White Paper:

Science of SAM: Why animation is good for the classroom

by Brian E. Gravel, Tufts University

Introduction

Animations have been used in classrooms for decades as means for teaching students science concepts. However, using animations as demonstrations has produced mixed results in terms of student learning (Morrison & Tversky, 2001; Morrison, Tversky, & Betrancourt, 2000). Criticism of animation has largely been due to the fact that, until recently, students have not been given the opportunity to generate these animations themselves, only to view them. There is a marked difference between students viewing an animation and students generating animations of their own. Expressing ideas in animated form, where the user has control over space and time, has important implications for science education. This thesis is grounded in the literature and theory, which are summarized in this white paper explaining why student-generated animation is valuable for classrooms.

The Fundamental Principles of SAM Animation

SAM Animation is supported by literature and theory related to a constructivist perspective, which purports that students construct understanding through experiences interacting with the natural world (Piaget & Inhelder, 1969). Everyday students observe, explore, and experiment with the world around them, and they must make sense of that world by inventing their own explanations. SAM Animation is a new tool for helping students express their understandings in unique, personally-meaningful, and generative ways.

There are few restrictions when it comes to using SAM Animation; that is, students are free to use markers and white boards, construction paper, physical manipulatives, body motions, or whatever they wish in the creation of their animations. By turning the students' desktops into the creation space, as opposed to the computer screen, we can capitalize on some of the inherent benefits of moving objects with one's hands. The student creates an animation that belongs to him or her and that expresses his or her unique and often idiosyncratic way of seeing the world; the animation becomes an artifact for reflection and eventual revision of one's understanding. The belief that working with one's hands is crucial to developing more sophisticated understandings about the natural and man-made world is securely situated in Seymor Papert's notion of *constructionism* (Papert, 1980; Papert & Harel, 1991). Papert believes, in essence, that when you build in the world, you build with your mind. And, this is one of the hallmark principles of SAM Animation. Alongside ***constructionism***, the concepts of ***flow***

(Csikszentmihalyi, 1991), ***external representation*** (Brizuela & Earnest, 2007; diSessa, 2004; Goldin, 1998; Goldin & Shteingold, 2001; Gravel & Brizuela, 2009; Kaput, 1991, 1998; Lehrer & Schauble, 2002; Nemirovsky & Tierney, 2001; Pérez Echeverría & Scheuer, 2009), ***engagement*** (Assor, Kaplan, & Roth, 2002; Leonard, Davis, & Sidler, 2005; Lepper & Cordova, 1992), ***story*** (Martin & Miller, 1988; Rowcliffe, 2004; Wellington & Osborne, 2001), and working in ***time*** form the six core principles of SAM Animation. Each principle is briefly described below to formulate the "Science of SAM," a rationale for why student-generated animation is a powerful tool for the classroom.

1. Constructionism

Active learning, hands-on learning, and a variety of other terminology has been created and adopted throughout the years as ways of describing meaningful learning experiences for children. Seymour Papert's framework, constructionism, builds on constructivist work by suggesting that learning happens best when the individual is building some measure of external artifact (Papert, 1980; Papert & Harel, 1991). Others have shown that this ownership causes the students to think more critically, become more excited and invested, develop greater conceptual mastery of the domain, and retain the material better than in forms of instruction in which information is delivered to students (Bransford, Brown, & Cocking, 1999; Fredericks, Blumenfeld, & Paris, 2004; Hake, 1998). More simply, when students build with their hands, constructing some kind of physical artifact or space, they are also engaging their minds with the ideas. Many software simulations and construction environments keep the student on the computer screen for the entirety of the activity. While there are clear, proven benefits for computer-based activities, SAM Animation takes a different approach by bridging the physical world with the digital world. Building an animation in the physical world helps to ensure that the student focuses on the content, and less so on operating the software itself.

2. Flow

Mihaly Csikszentmihalyi (1991) introduced the concept of *flow*, which involves matching of one's abilities and competencies to the level of difficulty of the problem. For example, an expert in a field when posed with a relatively simple problem will feel boredom or disinterest, because the problem is essentially "too easy." Conversely, a novice in some field when posed with a challenging problem will feel a sense of anxiety or confusion. *Flow* is the zone, or environment in where students engage with problems that are matched to their levels of understanding and competency. In traditional classrooms, differentiating instruction such that all learners are challenged, interested, and motivated is difficult to achieve. Students' abilities vary greatly in any given classroom, and quality educational experiences must take this into account. With SAM Animation, the level of the difficulty can be varied within the same context (e.g., making an animation explaining constant velocity) to challenge students at different levels. A student struggling with the concept can approach the animation from a conceptual, qualitative perspective. A student with greater understanding can take on a mathematical representation of the problem with animation as well. Thus, learning becomes rich and fun, because it is adequately challenging for each student in the classroom.

3. Representation

For centuries humans have examined the ways in which we represent understanding externally (Olson, 1994). Either through written language, spoken language, drawings, or gestures, the external artifacts and productions we produce are the hallmark achievement of humans as a species. For students, an ability to place ideas in the external world is an important and powerful process for generating understanding (Kaput, 1991, 1998). For teachers, the only real evidence they have of what students know is what they say, write, draw, build, or with SAM, what they animate. These animations are new lenses for viewing the ideas that students hold and the ways they express those ideas. For the student, the animation serves as a new way to express understanding and to review and revise that understanding in subsequent representations. Many researchers have shown that students can invent representations (Brizuela & Earnest, 2007l; diSessa, 2004), that external representations are powerful thinking tools (Lehrer & Schauble, 2002; Nemirovsky & Tierney, 2001; Pérez Echeverría & Scheuer, 2009), and that multiple representations can be powerful for students (Brizuela & Earnest, 2007; Gravel & Brizuela, 2009; Goldin, 1998; Goldin & Shteingold, 2001). With SAM Animation, the freedom to work with a variety of representational forms allows students to explore their ideas and develop more sophisticated understandings.

4. Engagement

The ubiquity of technological tools and gadgets in students' lives in today's age is incredible. Students have iPods, video games, online social media tools, and a seemingly limitless supply of new technologies to explore everyday. Therefore, when students take part in school lessons centered around technology, it is important that these tools are relevant and exciting. Among Pixar, Dreamworks, and the multitude of gaming environments, animation is incredibly popular, and it truly engages children. In an educational setting, providing some measure of relevance (either through the tool or the activity) has been shown to help students engage in learning and to stay interested (Assor, Kaplan, & Roth, 2002; Leonard, Davis, & Sidler, 2005; Lepper & Cordova, 1992). Thus, SAM Animation creates an engaging and relevant environment for students where they are able to take ownership over a project that is interesting, and that helps them stay focused on the educational content in question.

5. Story

Storytelling is most commonly used in the humanities as a means for getting students interested and engaged with literature, history, or social studies topics. However, professional scientists, too, engage in a form of storytelling when they use oral language, written language, graphs, and images to communicate their findings. Thus, telling the story of science is a natural activity that can engage students in topics they find uninteresting otherwise (Martin & Miller, 1988; Wellington & Osborne, 2001). For many students, science exists in a vacuum with little context or connection to the students' everyday lives. Taking a science topic, such as gravity, and telling a story about that topic that involves personal experience keeps the science alive for students (Rowcliffe, 2004).

6. Time

The final principle of SAM Animation offers a new perspective on learning about processes (i.e., changes of time) in science, related specifically to animation. An animation is a series of individual still images, called frames. Each frame can be conceived of as an instance in time - representing one particular moment. For the student generating an animation, he or she works on specific frames one at a time, while being mindful of the previous frame *and* the upcoming frame. That is, in the construction of any given frame, the student is thinking across at least three points in time - students know where they came from and where they are going. Animation considered in such a light uncovers the inherent temporal component of the medium. In other words, SAM Animation forces students to think in time (see Figure 1). When attempting to make sense of changes that occur over time, one of the greatest challenges students face is recognizing what, exactly, is changing. Taking large-scale changes and breaking them down into small increments spread over a number of discrete frames helps the student to make sense of the changes that are occurring. Take constant velocity, for example. If a student generates an animation showing an object moving at a constant speed, he or she will quickly notice that for each equal time interval, the object moves the same distance. However, for an object accelerating, in

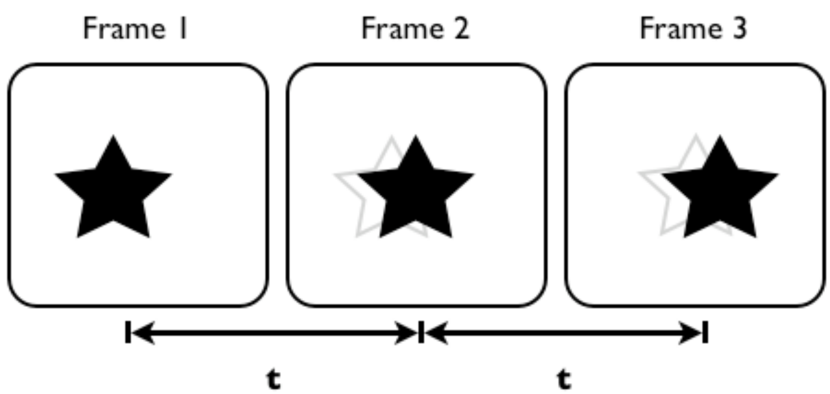

Figure 1. Image depicts how working on frame 2 requires knowledge of frame 1 as well as where things will be in frame 3. The time interval remains consistent, thus, the student is being forces to think over a period of time.

each equal time interval, the distance moved will increase every frame. Breaking concepts like kinematics down into small changes helps students to see what rates and change-over-time processes are all about. For the teacher, both the movies and the discussions the students engage in while using SAM Animation become new windows for observing how the students are making sense of the processes and where the students' struggles may lie.

Conclusion

SAM Animation is simple, easy-to-use software for the classroom. Based on the six principles described - constructionism, flow, representation, engagement, story, and time - SAM provides students and teachers with opportunities for meaningful and rich learning experiences. Putting the power of making ideas come alive in the hands of students gives them new tools and perspectives for seeing the science, as well as giving them ownership over the movies they make.

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